THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Hydrogen-Oxygen Fuel Cells: Use of Nickel Electrodes

F. T. BACON: 'Research into the Properties of the Hydrogen-Oxygen Fuel Cell.' *Beama Jnl.*, 1954, vol. 61, Jan., pp. 6-12.

In recent years there has been renewed interest in the possibility of using the fuel cell for producing electrical energy direct from coal, or as a means of storing electricity on a large scale. This article gives an account of work which has been carried out, over the past twenty years, in the University of Cambridge. The author opens with a historical survey of the earlier work which had been done on this subject, and subsequently describes various stages of his own research from about 1932 onwards, which has resulted in developments promising a practically useful future for this type of cell.

The design and operation of the various cells investigated, and of the most recent model, are described, with illustrations. With regard to materials of construction, it is noted that, in the present cell, the electrodes are of porous nickel, the main cell parts are of nickel-plated steel, and the pipework is of nickel.

After reviewing the present stage of development, the author mentions problems which are as yet unsolved. Finally, he discusses the advantages and limitations of the hydrogen-oxygen cell and the spheres of application in which, when it has been fully developed, it would be likely to prove economic.

NICKEL

Nickel in Canada

A. C. HOLM: 'Electrochemical and Electrometallurgical Industries of Canada. Part III. Ontario and Manitoba.' *Jnl. Electrochemical Soc.*, 1954, vol. 101, Feb., pp. 41C-9C.

This article opens with a concise description of the natural features of the province of Ontario and its industrial importance, the raw materials which are of significance to the electrochemical and electrometallurgical industries, and the electric-power resources available. Later sections cover individual industries in which electrochemical methods of production are used. The first of these sections is concerned with nickel and copper, giving an account of the plant and processes in operation under the control of International Nickel Company of Canada. Reference is also made to Falconbridge Nickel Mines, Ltd., which is the other large nickel-mining company in that area. Matte produced at the Falconbridge smelter is shipped to Norway for refining.

Occurrence of Nickel in Oil Sand

J. SCOTT, G. A. COLLINS and G. W. HODGSON: 'Trace Metals in the McMurray Oil Sands and Other Cretaceous Reservoirs of Alberta.' *Canad. Mining and Metallurgical Bull.*, 1954, vol. 47, Jan., pp. 36-42; *Trans. Canad. Inst. Mining and Metallurgy*, 1954, vol. 57, pp. 34-40.

Investigation of the occurrence of three trace metals (vanadium, nickel, and iron) in the oil sand of the McMurray region of Alberta showed remarkable uniformity in samples of the oil obtained from widely separated points in the oil-sand area. A typical analysis showed (p.p.m.) V_2O_5 360, NiO 93, Fe_2O_3 106. Comparison of the oil from these sands, on the basis of metals content, with crude oils found in other Cretaceous reservoirs showed an almost constant proportion for the vanadium and nickel oxides, and it is concluded that the oil-sand oil is in no way unique among crudes.

Ammonia Pressure Leach Process for Extraction of Nickel from Nickel Sulphide Concentrate

F. A. FORWARD: 'Ammonia Pressure Leach Process for Recovering Nickel, Copper and Cobalt from Sherritt Gordon Nickel Sulphide Concentrate.' *Canad. Mining and Metallurgical Bull.*, 1953, vol. 46, Nov., pp. 677-84; disc. p. 684: *Trans. Canad. Inst. Mining and Metallurgy*, 1953, vol. 66, pp. 363-70.

During the past seven years the Lynn Lake Mine, situated about 150 miles north of Sherridon, in Manitoba, has been actively developed by Sherritt Gordon Mines, Ltd., resulting in the establishment of a proved reserve of over 14,000,000 tons of ore containing nickel 1·223, copper 0·618, per cent., with some cobalt.

This paper describes the research and development programme which has led to the discovery and practical application of an ammonia pressure leaching process for extraction of nickel, copper and cobalt from the concentrate derived from the Lynn Lake ore.

The process involves treating the nickel-copper-cobalt-iron sulphide concentrates under pressure with air and ammonia, to dissolve the valuable metals and most of the sulphur, leaving the iron and other impurities in a tailing which is discarded. The copper is first separated from the solution as sulphide, by a boiling operation, the nickel is then precipitated by hydrogen under pressure, the cobalt is removed and purified, and the end solutions are evaporated to produce ammonium sulphate. Details of work in the pilot plants are given, the chemistry of the process is discussed, and costs of the research involved are considered in relation to the savings to be anticipated from adoption of the process for large-scale extraction.

Spontaneous Hall Effect in Nickel and Nickel Alloys

J. SMIT and J. VOLGER: 'Spontaneous Hall Effect in Ferromagnetics.' *Physical Rev.*, 1953, vol. 92, Dec. 15, pp. 1576-7.

The Hall voltage in ferromagnetics at saturation can be expressed in the form:—

$$E_y/i_x = \rho_{yx} = -\rho_{xy} = A_H \cdot B_z + \rho_{SH}$$

A_H is the normal Hall coefficient and ρ_{SH} the spontaneous Hall resistivity. The present authors give a table showing results of measurements of Hall coefficient, spontaneous Hall resistivity, and electrical resistivity of the following materials:—

Nickel (various grades)
Nickel-copper alloys (copper 9 and 18 per cent.)
Nickel-iron-copper alloys (92·5/2·5/5 and 85/5/10 per cent.
Nickel-cobalt alloys (cobalt 10, 20 and 30 per cent.)
Nickel-iron alloys (iron 10·5 and 16 per cent.)
Nickel-aluminium alloy (aluminium 8 per cent.)
Nickel-silicon alloy (silicon 6 per cent.)
Nickel-tin alloy (tin 3 per cent.)

Effect of Tension on Thermoelectric Properties of Nickel

A. J. MORTLOCK: 'The Effect of Tension on the Thermoelectric Properties of Metals.' *Australian Jnl. Physics*, 1953, vol. 6, Dec., pp. 410-19.

Measurements were made over the temperature range 20°–400°C. on the eleven metals shown below, using specimens of known purity: copper, silver, gold, platinum, palladium, nickel, aluminium, titanium, molybdenum, iron, tungsten. Evidence was obtained that the magnitude of the general effect depends on the purity of the specimen.

Sorption of Gases by Thin Layers of Nickel

W. SCHEUBLE: 'Sorption Properties of Thin Layers of Nickel.' *Zeitsch. f. Physik*, 1953, vol. 135, pp. 125-40.

In the experiments reported nickel was evaporated *in vacuo* onto the internal surface of a glass vessel into which the gas (oxygen or hydrogen) was then introduced. Deductions regarding the behaviour of the system are drawn from measurements of pressure. The conclusions reached are summarized in *Chemical Abstracts*, 1953, vol. 47, No. 10, p. 10,950.

Relation between Hydrogen Overvoltage and Catalytic Activity

E. CREMER and R. KERBER: 'Investigation of the Relationship between Hydrogen Overvoltage and Catalytic Activity in Metal Surfaces.' *Zeitsch. f Elektrochemie*, 1953, vol. 57, pp. 757-62.

Various types of catalytic material (including nickel, cobalt, copper, copper-zinc alloys and nickel-iron-molybdenum alloys) show a relationship between their catalytic activity and the rate of electrolytic precipitation of hydrogen at a given hydrogen overvoltage. This observation offers the possibility of determining the efficiency of a catalyst by means of the value of the current density at a given overvoltage. The experiments recorded were made on powders and, in the case of copper and of nickel, also on sheet material. The influence of the physical condition of the metallic material, on catalytic activity and overvoltage characteristics, was studied.

Nickel Catalysts in Precipitation of Vanadium from Aqueous Solutions

R. N. O'BRIEN, F. A. FORWARD and J. HALPERN: 'Precipitation of Vanadium from Aqueous Vanadate Solutions by Reduction with Hydrogen.' *Canad. Mining and Metallurgical Bull.*, 1953, vol. 46, Nov., pp. 673-6; *Trans. Canad. Inst. Mining and Metallurgy*, 1953, vol. 66, pp. 359-62.

This paper reports work done in the Department of Mining and Metallurgy, University of British Columbia, Vancouver, in the course of research directed towards improvement of methods for treating vanadium-bearing ores. The authors present data demonstrating that vanadium salts in aqueous carbonate solutions (as obtained at one stage in leaching of the ore) can be reduced with gaseous hydrogen in the presence of a nickel catalyst. The experiments recorded include determinations of the rate of precipitation of vanadium in the presence of varying amounts of the nickel-powder catalyst. The reaction is entirely catalytic in character: the catalyst is not consumed or altered by the reaction, and can be re-cycled indefinitely. Recovery of vanadium is complete and consumption of the reagent is negligible, thus rendering the process economic, even for low-grade solutions.

Hydrogen-Oxygen Fuel Cells: Use of Nickel Electrodes

See abstract on p. 40.

Determination of Trace Amounts of Iron in Nickel

D. W. MARGERUM and C. V. BANKS: 'Spectrophotometric Determination of Iron in Vanadium, Chromium, Manganese, Nickel, and Zinc.'
Analytical Chemistry, 1954, vol. 26, Jan., pp. 200-2.

The wide extent of the occurrence of iron impurities in metals and their salts frequently necessitates the determination of trace quantities of this element. Spectrographic methods are in many cases inconvenient, requiring development of new procedures and working curves, with the result that the spectrophotometric ferroin method is often preferred. In the work reported by the present authors the ferroin method is applied to new systems, by utilization of differing kinetic rates and extraction techniques. The slow rate of reaction of vanadium, chromium, and nickel with 1, 10-phenanthroline permits quantitative formation of the tris (1, 10-phenanthroline) iron (II) ion, which is then extracted as the perchlorate salt into a nitro-benzene phase, in which its absorbence is determined. Reaction rates of the first transition series metal ions with 1, 10-phenanthroline are classified and deviations from recent theoretical approaches are discussed. Rapid, sensitive, and accurate procedures are given for determination of γ to 200 γ of iron in vanadium, chromium, manganese, nickel and zinc. It is considered that the ferroin perchlorate extraction technique should be applicable also to other systems.

Interactions of Nickel with Oxides at Elevated Temperatures

G. ECONOMOS and W. D. KINGERY: 'Metal-Ceramic Interactions: II. Metal-Oxide Interfacial Reactions at Elevated Temperatures.' *Jnl. Amer. Ceramic Soc.*, 1953, vol. 36, Dec. 1, pp. 403-9.

Report of investigation of interfacial reactions of beryllium, molybdenum, niobium, nickel, silicon, titanium, and zirconium with dense specimens of the following oxides: Al_2O_3, BeO, MgO, ThO_2, TiO_2 and ZrO_2. The studies were made at temperatures of 1400°, 1600° and 1800°C. In general, the reactions occurred in the order which would be indicated by thermodynamic calculations. There was little or no reaction at 1400°C., but considerable reaction was observed in many of the systems at 1800°C. The systems Ni-BeO, Ni-Al_2O_3, Ni-TiO_2, NiZrO_2, Ni-MgO, and Ni-ThO_2 were, however, among those which, at 1800°C., showed no physical alteration of the metal-ceramic surface.

ELECTRODEPOSITION AND OTHER COATING METHODS

Plating Developments in 1953

N. HALL: 'Technical Developments of 1953.' *Metal Finishing*, 1954, vol. 52, Jan., pp. 52-61.

A review, supported by 311 *references to the literature*.

The subject is dealt with in sections relating, respectively, to cleaning and pickling, polishing, plating on individual metals, metallic coatings (nickel, chromium, other metals, alloys); metallizing by non-electrolytic processes; conversion films and corrosion preventatives; testing and control; treatment and disposal of wastes, and miscellaneous items of interest. In the nickel section attention is directed to 24 items of original technical and patent literature.

Nickelume Bright Plating Process

C. G. RISING: 'New Plating Process Deposits Nickel Brighter, Faster.' *Iron Age*, 1953, vol. 172, Dec. 24, pp. 78-81; see also *Product Finishing*, 1954, vol. 7, Jan., pp. 66-70.

This article records some experience with the Nickelume process developed by Hanson-Van Winkle-Munning Company (see *Nickel Bulletin*, 1953, vol. 26, No. 12, p. 206). The information given has specific reference to the use of the process in plating loose-leaf binders and folders of many shapes, sizes and types. Economies in maintenance and improved plating results are reported.

The bath used contains (oz./gal.) nickel sulphate 40, nickel chloride 6, boric acid 5, with two types of addition agent and a pit-inhibiting substance. Temperature is about 120°F. (50°C.) and the bath is operated at 1-1½ v. Current densities of 10-100 amp./sq. ft. can be used: it is stated that with a current density of 40 amp./sq. ft. a plate thickness of 0·00015-0·0002 in. is obtained in 10 minutes. Cathode efficiency is of the order of 96-98 per cent. In the plating operations described, no agitation is required except that provided by the slow motion of the work passing through the tank on the conveyor. The solution is continually purified by selective electrolysis.

As in earlier notices relating to this process, the necessity for thorough rinsing at various stages is emphasized.

Bright Nickel Plating: Review of Processes

'Bright Plating Processes.' *Industrial Finishing*, 1954, vol. 6, Jan., pp. 413-21.

This article is a review of the principal processes used for electrodeposition of bright coatings of copper, zinc, white brass, nickel, and chromium. In each section details are given of bath compositions and operating techniques. The processes described for bright nickel plating include those based on additions of sulphonic acids and those in which cobalt-nickel baths are used. Sources of supply, and proprietary rights in the respective processes are indicated.

The information in the body of the text is supplemented by a list of proprietary brighteners used in Great Britain and in U.S.A., and of the patents governing them.

Electrodeposited Nickel Coatings for Protection of Molybdenum from Oxidation

See abstract on p. 48.

Nickel+Chromium Plating of Plumbing Fixtures

T. STODDARD: 'Semi-Automatic Plating Pays Where Sizes, Shapes, Vary.' *Iron Age*, 1954, vol. 173, Jan. 14, pp. 122-4.

The author describes the plant and practice in a plating shop treating shower components, valves and other plumbing fixtures. Semi-automatic, semi-manual operation is claimed to give the combination of rate of output and quality of product required. For brass parts, the plating cycle involves (1) alkaline cleaning for 20 seconds, followed by reverse alkali cleaning for 5 seconds, dipping in a 20 per cent. sulphuric-acid solution, and final rinsing;* (2) copper plating in a Rochelle strike bath; (3) rinsing, dipping in a 15 per cent. sulphuric-acid neutralizing bath and re-rinsing; (4) nickel plating in a bright bath, where in a 6-minute treatment a deposit 0·00015-0·00020 in. thick is produced. (The nickel-plating step is the first mechanized operation in this plant.) After rinsing, the parts are passed to the chromium-plating tank, but, prior to plating, holes in the work which would cause gassing or improper plating are plugged with corks and re-racked. This manual step is claimed to be an essential in securing high quality and a low rate of rejects in work of the type processed in this plant. Chromium is deposited to a depth of 0·000015-0·000020 in. thick, after which the parts are dipped in a drag-out tank, given a weak-alkali dip and finally hot-water rinsed, dried, and packed.

*For zinc-base castings a slightly modified cycle is used.

NON-FERROUS ALLOYS

Foundry Production of Non-Ferrous Metals and Alloys

A. J. MURPHY (Editor): 'Non-Ferrous Foundry Metallurgy. The Science of Melting and Casting Non-Ferrous Metals and Alloys.' *Published by Pergamon Press, Ltd., London*, 1954; 497 pp. Price 70s.

It is pointed out in the editorial preface that in the foundry industry empirical procedures and ad-hoc treatments of recurring problems have persisted longer than in other branches of applied metallurgy, but that there has gradually been built up a fund of scientific knowledge which can be used for the rational study and control of industrial melting and casting. It is the aim of this book to integrate scientific and practical knowledge into a manual which, by providing reference information of an authoritative character, will make a practical contribution to commercial and technical progress in the non-ferrous foundry industry.

The subject matter is presented in the form of a series of monographs, written independently by specialists in various branches of the non-ferrous field: the thread which runs throughout the book is the attempt to translate scientific theory into successful practice.

Chapter 1 is an introductory survey of some of the principal properties of metals and alloys in the solid and in the liquid states, and this is followed by more specialized chapters, the scope of which is indicated below:—

Chapter 2. D. C. G. LEES: 'Some Properties of Liquid Metals.'

Chapter 3. D. C. G. LEES: 'The Solution of Gases in Liquid Metals.'

Chapter 4. W. A. BAKER: 'Solidification.'

Chapter 5. 'Non-Ferrous Foundry Technology.'
- J. E. GARSIDE: 'Production of Metal Castings.'
- V. KONDIC: 'Casting of Ingots for Subsequent Use.'
- J. E. GARSIDE: 'Industrial Melting of Non-Ferrous Metals and Alloys.'

Chapter 6. 'Properties and Testing of Castings.'
- W. A. BAKER: 'Metallurgical Principles.'
- E. SCHEUER: 'Mechanical Properties of Castings.'
- R. J. M. PAYNE: 'Influence of Form and Environment on Endurance of Castings.'
- C. E. RANSLEY: 'Measurement of Gas Content of Cast Metal."
- O. VAUPEL: 'Non-Destructive Testing of Castings.'

Chapter 7. 'Casting Alloys.'
- W. A. BAKER: 'Copper-base Alloys.'
- F. HUDSON: 'Nickel-base Alloys.'
- R. T. PARKER: 'Aluminium-base Alloys.'
- F. A. FOX: 'Magnesium-base Alloys.'
- L. A. J. LODDER: 'Zinc-base Alloys.'
- A. STREET: 'Tin-base and Lead-base Alloys.'
- J. C. CHASTON: 'Silver, Gold, Platinum and their Alloys.'

The nickel-base alloys are discussed in seven groups, relating, respectively, to the following types of material:—

Nickel castings
Nickel-copper, nickel-copper-silicon and related alloys
Nickel-copper-tin, nickel-copper-tin-lead and related alloys
Nickel-chromium-iron alloys
Nickel-molybdenum, nickel-molybdenum-chromium and related alloys
Nickel-silicon alloys
Nickel-titanium, nickel-beryllium alloys, etc.

A supplementary note in this section deals with manganese-copper-nickel alloys.

Each chapter in the book contains much tabular data and many illustrations, and the letterpress is supported by extensive *bibliographies*.

Structure of Gold-Nickel Alloys

P. A. FLINN, B. L. AVERBACH and M. COHEN: 'Local Atomic Arrangements in Gold-Nickel Alloys.' *Acta Metallurgica*, 1953, vol. 1, Nov., pp. 664-73.

Local atomic arrangements in gold-nickel alloys have been determined as a function of composition, by observations of diffuse X-ray scattering. Measurements were made at −190°C. on alloys quenched from above the solubility gap, since there was experimental evidence that the high-temperature atomic configurations can be retained on quenching. The X-ray data reveal that above the solubility temperature these alloys exhibit a preference for unlike neighbours and that they have a short-range order analogous to that found in copper-gold alloys.

The sizes of the atoms in the solid solutions were measured from the diffuse scattering. The gold atom in solution is smaller than in the pure metal, but larger than the average atomic dimension calculated from the lattice parameter of the solution. Correspondingly, the nickel atom in solution is larger than in the pure metal, but smaller than the average atomic dimension of the solution. The size of each atom varies with the composition of the solution.

Spontaneous Hall Effect in Nickel and Nickel Alloys

See abstract on p. 41.

Nickel-containing Coinage

'Eighty-Second Annual Report of the Deputy Master and Comptroller of the Royal Mint, 1951.' *Published by Her Majesty's Stationery Office*, 1953, 91 pp. + index.

This issue includes a historical review of the activities of the Royal Mint since the drawing up, in 1851, of the basis of its present constitution. It also embodies the normal statistical information on U.K. coinage, and on medals struck, assays made, etc. (including the verdicts of the jury at the trial of the Pyx, May, 1952). Details are given of cupro-nickel and nickel-brass currency, including the issue of the Festival of Britain crown piece. Reports of associated Mints in Australia are also given.

A feature of the report is a series of photographs of medals struck during 1951 (including the Rosenhain Medal of the Institute of Metals), and an illustrated account of the movement of metal involved in striking coins and medals.

Monel Equipment in Fluorine-Disposal Plant

See abstract on p. 51.

Magnetostriction of Nickel-Cobalt Alloys

M. YAMAMOTO and R. MIYASAWA: 'Longitudinal Magnetostriction in Nickel-Cobalt Alloys.'
Science Repts., Research Inst., Tôhoku Univ., Ser. A., 1953, vol. 5, pp. 22-33.

Report of measurements in magnetic fields up to 900 oersted, on about fifty annealed nickel-cobalt alloys. Data on longitudinal magnetostriction as a function of composition, magnetic field, and intensity of magnetization.

See also—
M. YAMAMOTO and R. MIYASAWA: 'On the Magnetostrictive Constants of Face-Centred Cubic Nickel-Cobalt Alloys,' *ibid.*, pp. 113-23.

Plastic Properties of Nickel-Iron and Nickel-Cobalt Alloys

See abstract on p. 45.

Nickel-Chromium-Molybdenum Alloys and Related Binary Systems

D. S. BLOOM and N. J. GRANT: 'An Investigation of the Systems Formed by Chromium, Molybdenum, and Nickel.' *Jnl. of Metals*, 1954, vol. 6, Feb., Sect. 2; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 261-8.

The major aim of the work described was to determine the ternary phase diagram nickel-chromium-molybdenum at and above 1250°C., giving also sufficient attention to the constitution at lower temperatures to permit an understanding of the conditions existing within the range of specialized interest. As a basis for examination of the ternary system, the relevant binary systems were re-examined, with resulting suggestion of some changes in accepted constitutional diagrams. Attention is also directed to the significance of the fact that the element chromium undergoes a crystal transformation at a temperature near its melting point: the bearing of this change on alloy systems in which chromium is a constituent is indicated.

As a result of the observations made (full details of which are reported) it is suggested that some changes be made in the phase diagram of the *molybdenum-nickel* system, in the regions of the eutectic and peritectic reactions. In the *chromium-nickel* system some interesting phenomena are recorded concerning the intermediate structure associated with the eutectoid reaction. It is shown that the retained high-temperature phase can be decomposed by annealing or cold-working near room temperature. It is concluded that the *chromium-molybdenum* diagram, as at present accepted, is incorrect, and although the authors cannot yet propose full revision, they suggest some changes. The work has resulted in full development of the 1250°C. section of the *chromium-molybdenum-nickel* system, indicating the shape of the σ-phase field at that temperature. The existence of another ternary compound, designated the *P* phase, was corroborated. The liquidus surface of the ternary system was developed from the liquidus temperatures, as determined for each alloy by thermal analysis. The authors suggest a system of invariant reactions existing above 1250°C.

Nickel Catalysts in Precipitation of Vanadium from Aqueous Solutions

See abstract on p. 41.

Aluminium-Nickel-Zinc Alloys: Constitutional Study

G. V. RAYNOR, C. R. FAULKNER, J. D. NODEN and A. R. HARDING: 'Ternary Alloys formed by Aluminium, Transitional Metals and Divalent Metals.'
Acta Metallurgica, 1953, vol. 1, Nov., pp. 629-48.

A general survey has been made, by metallographic and X-ray methods, and by the examination of extracted crystals, of the constitutions of the alloys of aluminium and zinc with iron, cobalt and nickel, of aluminium and magnesium with cobalt, and of aluminium and beryllium with manganese and iron. In the latter two systems new ternary compounds $Mn_3Be_2Al_{15}$ and $Fe_3Be_7Al_7$ were discovered in equilibrium with the aluminium-rich solid solution. No ternary compounds in equilibrium with the aluminium-rich alloys occur in the other systems studied; an unidentified ternary phase separates from zinc-rich alloys in the system aluminium-nickel-zinc, but does not enter into equilibrium with the zinc-rich solid solution.

The outstanding feature of the system aluminium-cobalt-zinc is the deposition, from zinc-rich melts, at low temperatures, of the high-melting phases CoAl and Co_4Al_{13} in addition to Co_2Al_9; these phases persist in equilibrium with the zinc-rich solid solution.

Similarly, in the system aluminium-nickel-zinc, Ni_2Al_3 as well as $NiAl_3$ is found in zinc-rich alloys, while in the system aluminium-cobalt-magnesium the high-melting phase CoAl enters into equilibrium with the magnesium-rich solid solution. By contrast, only a phase derived from $FeAl_3$, and none of the more iron-rich aluminium-iron compounds, is found in equilibrium with zinc in the system aluminium-iron-zinc.

The main features of the equilibria are discussed in terms of the free energies of phases present, and the data, taken together with the results of previous work, lead to a better understanding of the factors affecting the formation of aluminium-rich ternary compounds.

Nickel Antimonides

T. ROSENQVIST: 'Magnetic and Crystallographic Studies on the Higher Antimonides of Iron, Cobalt and Nickel.' *Acta Metallurgica*, 1953, vol. 1, Nov., pp. 761-3.

Report of investigation by magnetic, X-ray and optical goniometer methods.

NICKEL-IRON ALLOYS

Physical Properties of Nickel-Iron Alloys

MOND NICKEL CO., LTD.: 'The Physical Properties of the Nickel-Iron Alloys.'* *Publn.* 431*A*, 1954; 23 pp.

This publication, a revised edition of No. 431, gives an account of the general characteristics of nickel-iron alloys (constitution, mechanical properties, corrosion-resistance, and electrical and thermal properties), and draws particular attention to the unusual dilational properties of binary nickel-iron alloys and alloys of nickel and iron base containing controlled amounts of other elements.

Developments which have followed the early work of Guillaume are reviewed, the expansion characteristics of individual alloys are considered in relation to composition, purity and treatment, and some of the many uses of such alloys are described and illustrated.

Plastic Properties of Nickel-Iron and Nickel-Cobalt Alloys

V. F. ZACKAY and T. H. HAZLETT: 'Some Plastic Properties of Nickel Alloys.' *Acta Metallurgica*, 1953, vol. 1, Nov., pp. 624-8.

One phase of investigation involved in the study of phenomena associated with plastic deformation of metals is that of the mechanism of solid-solution hardening. Addition of any solute element to a pure metal strengthens the solvent, and it is generally agreed that lattice distortion of the host lattice, caused by foreign atoms, is one of the factors producing this effect. Differences in the relative sizes of the two atoms, and differences in their interaction, are among the causes of such distortion.

It has been shown that in aluminium the difference in valence of the solvent and the solute atoms, as well as the magnitude of the lattice strains, influences the degree of solid-solution hardening. There has been speculation in the case of the transition elements as to whether *d*-shell electrons are a significant factor in plastic deformation. The present paper gives preliminary results of an investigation planned to evaluate the rôle played by *d*-level.

Two alloy systems were selected for study, as being uniquely suited for the purpose, since, due to the only slight difference in atom size, the strain energy interaction should be small. The alloys used were of the compositions shown below:—

Nickel-iron: 2·55, 4·94 and 9·77 at.- per cent. iron.

Nickel-cobalt: 2·43, 4·60 and 8·69 at.- per cent. cobalt.

The examination comprised creep tests at 700°C., stress-strain determinations at room-temperature, tensile tests in the 300°–400°C. region, measurement of lattice parameters of the alloys, and electrical-resistivity measurements. Comparative tests were made on pure nickel.

The authors make the following summary of their conclusions:—

'Several physical and chemical properties of the ferromagnetic elements indicate an equivalence of solid-state bonding for nickel and cobalt. For example, the values of work of cohesion, compressibility, and oxidation potential are practically identical for nickel and cobalt. They are not the same for iron.

'Experimental data on the plastic properties of nickel-base cobalt and iron alloys support this conclusion. The addition of cobalt has only a small effect on tensile properties of pure nickel at room temperature and at elevated temperature. A similar behaviour is observed in creep tests of the same alloys. As might be expected, cobalt has practically no effect on the lattice parameter of nickel.

'Comparable tensile and creep data on nickel-iron alloys show that iron substantially solution-hardens nickel.

'In the case of pure nickel, a sharp discontinuity in plastic behaviour was noted at the Curie temperature, and may be tentatively explained on the basis of elementary domain theory.'

Spontaneous Hall Effect in Nickel and Nickel Alloys

See abstract on p. 41.

Production of Nickel-Aluminium-Cobalt-Iron Magnets

R. H. HERMANN: 'All-Electric Operation Features Modern Permanent Magnet Foundry.' *Foundry*, 1954, vol. 82, Jan., pp. 86-91, 206-12 (even numbers only).

A detailed account is given of the layout and operation of the permanent-magnet foundry of the Carboloy Department of General Electric Company, near Edmore, Michigan.

The charge compositions for the various alloys produced are shown in the table below: it is noted that 80-85 per cent. of the output is of the Alnico 5 grade.

A step-by-step description is given of melting, casting, ageing, demagnetizing and magnetizing treatments, and of final inspection methods.

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Alnico No.	Ni %	Co %	Al %	Cu %	Zr %	Fe %	Ti %
2	17·0	12·5	10·0	6·00		54·5	
3	25·0		12·0			63·0	
5	14·0	24·0	8·0	2·75	0·25	51·0	
6	15·0	24·0	8·2	2·75		48·5	1·55
7	18·0	25·0	8·5	3·25		40·25	5·0

Nickel-Iron Alloys in Waveguides

N. E. PRYSLAK: 'Metal-to-Ceramic Seals for Magnetron Waveguides.' *Electronics*, 1954, vol. 27, Jan., pp. 282-7.

The author describes a tungsten-iron metallizing process used in construction of sandwich-type metal-to-ceramic seals developed primarily for making vacuum-tight windows for magnetrons and other microwave electron tubes. Tubes having ceramic windows can be processed during exhaust at bakeout temperatures of 650°–700°C. and parts can be brazed, with the window in place, to the main section of the tube. The seal consists of a rectangular ceramic window interposed between two metallic window frames and brazed to the inner walls of a rectangular waveguide. For the waveguide and the metallic window frames a 51–49 per cent. nickel-iron alloy is used. A detailed and illustrated description is given of a typical unit.

In connexion with the metal-ceramic seals of the windows, a graph shows the thermal-expansion characteristics of the nickel-iron alloy and of two types of ceramic material. Prior to sealing, the ceramic surfaces are coated with a 90–10 tungsten-iron powder, and to confer improved 'wettability' the metallized surface is plated with nickel or copper. The preparation of the powder and the technique of metallizing are described.

CAST IRON

Ni-Hard Cast Iron: Data Sheet on Properties

MOND NICKEL CO., LTD.: 'Ni-Hard. A Summary of Properties.' *Publn.* 727, 1953; 3 pp.

Reprint of data sheet appearing in *Nickel Bulletin*, 1953, vol. 26, No. 10, pp. 162-4.

Addition Alloys for Production of Alloy Cast Irons

MOND NICKEL CO., LTD.: 'Addition Alloys for Making Ni-Hard, Ni-Resist and Other High-Duty Cast Irons.'* *Publn.* 710, 1953; 6 pp.

This publication gives details of the composition of four pre-alloys which contain nickel and other alloy elements in balanced proportions permitting close control of the composition, and hence the properties, of high-duty cast irons of various types. The pre-alloys mentioned are: N.H. Ingot, Nisiloy, N.C.C. Pig, and F. Nickel. The specialized function of each type, and the purpose for which it is specially well suited, are indicated, and source of supply is given.

CONSTRUCTIONAL STEELS

Weldability of Steels: Welding Research Council Handbook

R. D. STOUT and W. D. DOTY: 'Weldability of Steels.' *Published by Welding Research Council, New York*, 1953; 381 pp. Price 51s. 9d.

Work initiated by the Welding Research Council in 1936 was originally concerned solely with the effect of welding on steel, but the more fundamental approach to welding which has developed during subsequent years has led to the widening of the scope of the Council's investigations, to cover a study of the mechanical and metallurgical characteristics of steels *per se*, as influencing their reaction to welding.

Much information has been accumulated, as a result of research organized by the Council, practical experience in welding, and research work in many industrial organizations which have contributed towards the general pool of knowledge. The present book constitutes an attempt to bring together, and into related perspective, the various data which have thus been established, in order that a clearer understanding may be obtained of outstanding problems, and that lines for future research may be defined. It represents a consensus of opinion gathered from all branches of the welding industry and from many metallurgists concerned with research on the fundamental characteristics of steel.

An introductory chapter discusses the importance of welding as a method of assembly, the effects of welding on steel, the definition of weldability, and the scope of the monograph. This is followed by chapters dealing in detail with the following aspects of the subject: the various welding processes in relation to weldability; metallurgy in relation to weldability (constitution of steel, hardenability, thermal effects of welding, etc.); the mechanical and corrosion-resisting properties of steel in relation to weldability; factors affecting weldability in fabrication (types of unsoundness found in welds, and soundness as affected by the base metal, by joint design and by the welding procedure); the influence of variables in the base metal on weldability for service (composition, deoxidation, soundness, thermal and mechanical history, etc.); welding procedure as a factor determining weldability for service (effect of weld metal, heat-input and pre-heat, post-heat); weldability of individual steels; weldability tests.

The letterpress is supported by a *bibliography* of 200 references.

Based on knowledge available to date, a tabular summary has been made of welding procedures suitable for steels which, from this point of view, fall into three categories—

1. Compositions and thicknesses requiring no pre-heating, post-heating, or special electrodes for sound welding.
2. Compositions and thicknesses requiring some control over heat input, and requiring low-hydrogen electrodes or pre-heat, and generally post-heating, for sound welding.
3. Compositions and thicknesses requiring pre-heat, special welding techniques, and post-heating and/or peening, for sound welding.

A key to the steels mentioned shows the standard A.S.T.M. and A.I.S.I. specifications to which they conform.

Ultra-High-Tensile Nickel-Chromium-Molybdenum Steel for Aircraft

M. A. MELCOM: 'Ultra-High-Strength Steel for Aircraft Structures.' Reprint of paper from *Product Engineering*, Oct., 1953. see abstract in *Nickel Bulletin*, 1954, vol. 27, No. 1, p. 11.

Issued by International Nickel Co., Inc., 1954; 15 pp.

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HEAT- AND CORROSION-RESISTING MATERIALS

Nickel-Chromium Alloys Hardened with Titanium and Aluminium

R. NORDHEIM and N. J. GRANT: 'Ageing Characteristics of Nickel-Chromium Alloys Hardened with Titanium and Aluminium.' *Jnl. of Metals*, 1954, vol. 6, Feb., Sect. 2; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 211-18.

The nickel-chromium alloys hardened with titanium and aluminium, exemplified by Nimonic 80 and Inconel X, constitute one of the most important groups of alloys developed to meet the demand for materials which will retain their strength at elevated temperatures. In the temperature range 1200°-1500°F. (650°-815°C.) these alloys offer good resistance to creep and have been widely used in gas-turbine components.

The investigation reported in this paper was undertaken with the aim of obtaining a clearer understanding of the factors controlling the precipitation-hardening of such alloys, in order that the temperature range of useful service might be extended. Using a constant nickel : chromium ratio of about 4 : 1, the titanium and aluminium contents were each varied from 0 to 4 per cent. The major part of the study was made on alloys containing less than 0·06 per cent. of carbon. The heats used for study of precipitation hardening were poured into silica precision-casting investment moulds giving bars of $\frac{3}{8}$- and $\frac{1}{4}$-in. diameter, and the bars were homogenized for 45 hours at 2170°F. (1187°C.), resulting in an average grain size of about $\frac{1}{16}$-in. Subsequent heat-treatments comprised a 4-hour solution treatment at 2000°F. (1093°C.), followed by water quenching, and ageing at temperatures in the range 1250°-1800°F. (675°-980°C.). For all treatments at and above 1650°F. (898°C.) and for treatments of longer than 20-hours' duration at 1450° and 1550°F. (787° and 842°C.) an atmosphere of purified helium was used. The precipitation processes were studied by means of metallographic examination, hardness measurements, and measurements of electrical resistance at temperature. A detailed report is made on typical results obtained by all these methods, and the conclusions of the authors are correlated with those of earlier investigators.

The structural studies were supplemented by stress-rupture tests, at 1500°F. (815°C.), on some wrought alloys similar in composition to those used in the precipitation-hardening experiments. Before testing, the bars used in the stress-rupture tests were solution-heated for 8 hours at 2000°F. (1093°C.), air-cooled, and aged for 16 hours at 1300°F. (704°C.).

The authors find that their observations confirm the statement by HIGNETT in 1951 that the titanium- and aluminium-hardened nickel-chromium alloys of the Nimonic 80 type owe their high strength to the precipitation of an inter-metallic compound based on the cubic Ni_3Al phase, γ', but with aluminium partly replaced by titanium. This substitution, which increases the 'misfit' between the lattices of the γ' phase and the matrix, raises the creep-resistance and rupture strength of the alloys. Such increase is accompanied by a relatively large fall in ductility. It was found, however, that by raising the ageing temperature of the higher-titanium alloys in this group ductility can be improved without loss (and in some cases with a gain) in rupture strength. Substitution of titanium for aluminium appears to decrease the rate of growth and coalescence of γ', resulting in stronger alloys.

When the titanium-to-aluminium ratio of the alloys is increased beyond the solubility limit for titanium in Ni_3Al, the hexagonal Ni_3Ti phase, η, starts to precipitate. The precipitation rate of η is slow, as indicated by hardness; the increase in strength due to precipitation of this phase therefore occurs very slowly and may not be achieved at all in short-time or intermediate-length tests.

It is suggested that, in order to raise the useful service temperature for the nickel-chromium-base alloys, the titanium-to-aluminium ratio be increased towards the end of the homogeneity range for γ', and that the sum of the titanium and aluminium contents be increased within the limits permitted by fabrication or processing.

Annealing and Pickling of Nimonic Alloys

HENRY WIGGIN AND CO., LTD.: 'Annealing and Pickling of Nimonic 75 and Nimonic F.'* *Publn.* 672, 1954, 3 pp. (replacing Publn. 347).

Recent developments in technique and further production experience accumulated since the issue of the earlier publication are embodied in this brochure, which includes detailed recommendations on annealing conditions, and on three methods of descaling: (1) by use of acid pickles, (2) by treatment with alkaline liquor followed by acid dip, and (3) by treatment in fused alkali baths followed by acid pickling.

The publication contains a summary of the range of the Nimonic alloys now in commercial supply, with particulars of the specifications to which they conform and the numbers of the relevant British Patents.

Heat-Treatment and Working of High-Temperature Cobalt-Nickel-Chromium-Tungsten Alloy (Haynes 25)

H. A. BLANK, A. M. HALL, J. H. JACKSON, J. W. FRANK and W. K. ANDERSON: 'The Heat-Treatment and Working of Haynes 25 Alloy.'
Report by Battelle Memorial Inst.; issued as *U.S. Atomic Energy Commission Report BMI-814*, 1953; 31 pp.

The alloy which is the subject of this report was developed to give a combination of good mechanical properties and corrosion-resistance over a wide range of temperatures, combined with a substantial degree of ductility. The objectives of the work now described were to determine (1) the upper limit of hardness, produced by cold working, at which the alloy can be satisfactorily machined, and (2) the ageing conditions producing maximum hardness. Associated interests were improvement of machinability and response to

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heat-treatment, as well as wear-resistance, by modifications of composition. The basis composition of Haynes 25 is given as cobalt 52·6, chromium 20, nickel 10, tungsten 15, manganese 1·5, per cent., carbon 0·12 per cent. Influence of composition on ageing response was determined on alloys of this type modified by additions of titanium, aluminium and boron, and by carbon contents higher than those of the standard alloy. With a view to improving machining characteristics, additions of sulphur, selenium, and selenium+molybdenum were introduced.

From the large amount of experimental data presented in the report, the following conclusions are drawn:—

The cobalt-base alloy can be machined when work-hardened to Rockwell C-48. Ageing for 10 hours at temperatures between 1000° and 1300°F. (538° and 704°C.) produces maximum hardness: in material cold-worked 40 per cent. prior to ageing a hardness of Rockwell C-54 can be so produced. Surface hardness of material cold-worked from 0 to 30 per cent. is increased by shot-peening, but only to a depth of 0·002 in.

Optimum ageing response, after a given amount of cold work, was obtained in an alloy modified by additions of 1 per cent. each (by weight) of titanium and aluminium: a value of Rockwell C-54 was thus produced. The straight alloy (unmodified Haynes 25) gave a hardness of 50 after similar treatment.

No improvement in machinability resulted from the addition of sulphur, selenium, or selenium+molybdenum.

Wear tests on several of the modified alloys in the cold-worked condition showed a susceptibility to galling: the alloys containing 2 per cent. by weight of titanium and 0·2 per cent. of carbon gave the best performance in these tests, followed by one containing 0·10 per cent. of sulphur and 0·12 per cent. of carbon.

Oxidation Characteristics of Nickel-Chromium and Nickel-Aluminium Alloys

J. MOREAU and J. BÉNARD: 'Comparative Study of the Mechanism of Oxidation of Binary Iron-Chromium, Nickel-Chromium and Nickel-Aluminium Alloys.' *Comptes Rendus*, 1953, vol. 237, Nov. 30, pp. 1417-19.

As a continuation of investigations on iron-chromium alloys (*ibid.*, 1953, vol. 236, p. 85), the authors report observations on high-nickel nickel-chromium and nickel-aluminium alloys oxidized in air at suitable temperatures within the range 800°–1300°C.

As an example of phenomena occurring in the nickel-chromium series, they describe observations made on a binary alloy containing 5 per cent. of chromium. Examination of this alloy after oxidation revealed the presence of three layers:—

(1) in the interior of the metallic phase, in the immediate vicinity of its surface, was a layer composed of granules of Cr_2O_3 dispersed in pure nickel.

(2) an intermediate two-phase layer was composed of granules of nickel chromite ($NiCr_2O_4$) having the cubic structure characteristic of spinels, dispersed in a matrix of nickel oxide (NiO).

(3) at the surface which was in contact with the atmosphere there was a layer consisting of pure nickel oxide (NiO).

The nickel-aluminium alloy showed, after oxidation, characteristics which were closely similar to those found in the nickel-chromium series. Granules of alumina were dispersed in the interior mixed layer and granules of nickel aluminate were found in the two-phase layer.

These observations are discussed in relation to the earlier work on the iron-chromium alloys, and in the light of work reported on the oxidation of other groups of binary alloys in which (as in the nickel-chromium and nickel-aluminium alloys studied) the more oxidizable constituent is present in only small proportions.

Electrodeposited Nickel Coatings for Protection of Molybdenum from Oxidation

L. E. VAALER, C. A. SNAVELY and C. L. FAUST: 'Introductory Plating Studies on Protecting Molybdenum from High-Temperature Oxidation.'
Report by Battelle Memorial Inst.: issued as U.S. Atomic Energy Commission Report BMI-813, 1953; 20 pp.

The use of molybdenum at high temperatures (for which its mechanical properties would be suitable) is precluded by the 'catastrophic oxidation' to which it is subject, due to formation of highly volatile molybdenum trioxide, and resultant rapid disintegration of the metal.

Various methods have been proposed to inhibit the oxidation. The authors give reference to relevant publications, and it is noted that one of the most successful trials was with nickel cladding rolled onto the molybdenum. In the experiments now reported the protective capacity of electrodeposited nickel coatings was studied. Various pre-treatments were used in preparing the molybdenum for plating:—(1) a.c. electrolysis in hydrofluoric acid; (2) a dip in alkaline ferricyanide solution; or (3) a combination of anodic cleaning in alkali, a dip in nitric acid, and a dip in alkaline ferricyanide solution. In most cases a thin layer of chromium or iron was electrodeposited prior to deposition of nickel.

The nickel-plated samples were tested for tendency to blistering by heating in a vacuum (100 microns) furnace to 800°F. (426°C.). Similar specimens were subjected to 100-hour oxidation tests at 1800°F. and 2000°F. (981° and 1093°C.). The results were as follows:—

(1) *Blistering tests.* All deposits blistered except those on which iron had been deposited prior to the nickel.

(2) *Oxidation tests.* Nickel coatings one mil thick, deposited direct on molybdenum or over an undercoat of chromium, protected molybdenum from oxidation for 100 hours at 1800°F. (981°C.), but nickel over iron was not equally effective, in spite of the fact that such deposits were superior in the blistering test.

With regard to preparation of the molybdenum surface for plating, the indications obtained in the tests were that pre-treatment with alkaline ferricyanide is superior to that involving electrolysis in hydrofluoric acid solution.

Titanium Carbide-base Cermets having Nickel-containing Binders

W. L. HAVEKOTTE: 'Super Refractories for Use in Jet Engines.' *Metal Progress*, 1953, vol. 64, Dec., pp. 67-70.

This paper reports tests made by Firth Sterling, Inc., Pittsburgh, on a series of carbide-metal refractory materials of types similar to those made in U.K. by Hard Metal Tools, Ltd., and in Europe by Metallwerk Plansee, Reutte, Austria. The compositions of the materials investigated are shown in Table I below:—

Table I
Chemical Composition and Mechanical Properties of Titanium-Carbide Cermets

Grade	TiC	Ni	Co	Cr	Cr_3C_2	Density g./c.c.	Rockwell Hardness	Modulus of Rupture p.s.i.
FS-2	63·0	29·6	—	7·4	—	6·00	A-87·2	175,000
FS-5	63·0	—	25·9	11·1	—	6·15	A-89·5	158,000
FS-8	63·0	22·2	7·4	7·4	—	6·05	A-87·5	162,000
FS-9	50·0	30·0	10·0	10·0	—	6·40	A-82·5	170,000
FS-26	54·3	40·0	—	—	5·7	6·25	A-85·0	165.000
FS-27	42·9	50·0	—	—	7·1	6·55	A-81·0	180,000

The test specimens were made by the following procedure: Titanium-carbide and metal powders (325-mesh) were ball-milled together in steel mills, using tungsten-carbide balls and an inert organic liquid carrier. The powders were dried, mixed with paraffin, and pressed at room temperature. The resulting billets were sintered at 1500°-1800°F. (815°-980°C.), shaped to the required dimensions, and then fully sintered in a vacuum furnace at a temperature above 2000°F. (1093°C.). The exact temperature used in this operation was determined by the amount of binder incorporated in the cermet. The parts were then ground to shape, using diamond abrasive wheels.

It will be noted from the table that, in general, as the amount of binder increased the values for density rose, the hardness fell, and the modulus of rupture increased. The paper includes a photomicrograph showing structure typical of the cermets; it includes three phases: titanium-carbide-rich solid solution, chromium-carbide-rich solid solution, and binder. It was not found possible to identify the type of chromium carbide present.

Effect of temperature on tensile strength was determined on specimens of cermets FS-26 and FS-27, with the results shown in Table II.

For both specimens elongation at 1800°F. (980°C.) was 1-2 per cent.; at lower temperatures neither specimen showed measurable ductility. A graph showing effect of temperature on rupture strength for the FS-26 cermet in 30, 100, and 300-hour tests shows that 100-hour rupture fell from 59,000 p.s.i. (26·35 tons per sq. in.) at 1250°F. (675°C.) to 11,100 p.s.i. (4·95 tons per sq. in.) at 1800°F. (980°C.). At lower temperatures the cermet is slightly stronger than alloy X-40,* but at 1800°F. (980°C.) both materials have about the same strength. In the 300-hour rupture tests at 1300°F. (704°C.) elongation rose from 1 per cent. to approximately 8 per cent. at 1800°F. (980°C.).

Oxidation-resistance was tested by exposure to moist air at 1800°F. (980°C.) for periods up to 200 hours: specimens were removed from the furnace for examination after 5, 10, 25, 50, 100 and 200 hours. In most

* Cobalt 55, chromium 25, nickel 10, tungsten 7, per cent.

Table II

Temperature		Tensile Strength			
		FS-26		FS-27	
°F.	°C.	p.s.i.	t.s.i.	p.s.i.	t.s.i.
80	26·8	33,000	14·75	75,000	33·50
800	426	41,000	18·30	76,500	34·15
1200	648	48,000	21·45	75,000	33·50
1500	815	51,000	22·75	60,000	26·80
1800	980	41,000	18·30	35,000	15·65

of the tests the scale was strongly adherent, and the curve for weight-gain v. time shows a shape typical of materials forming a protective layer. Metallographic examination indicated that oxidation began in binder areas adjacent to the carbide particles. The mechanism suggested is as follows: The binder areas were originally rich in chromium. During the time in which the specimens were sintered, and later held at 1800°F. (980°C.) the chromium diffused into the carbide particles, leaving the adjacent binder areas deficient in chromium. After the binder areas adjacent to the carbide particles had oxidized the titanium carbide areas were next affected, and finally the binder regions rich in chromium were oxidized.

Coefficient of thermal expansion was measured on 2-in. samples: results are shown below:—

Temperature Range		Thermal Expansion $\times 10^{-6}$ per °F.	
°F.	°C.	FS-26	FS-27
68–212	20–100	5·6	5·8
68–392	20–200	5·9	6·0
68–572	20–300	6·0	6·1
68–752	20–400	6·0	6·0
68–932	20–500	6·0	6·1
68–1292	20–700	6·0	6·2
68–1472	20–800	6·0	6·2

The values are low compared with those characteristic of most iron- and nickel-base alloys, offering advantages in design of vanes and blade for use at high temperatures.

Resistance to thermal shock was found to be good, an unusual property in materials having such a low degree of ductility. It is suggested that their satisfactory behaviour in this respect may be due to their low thermal expansion and their high conductivity, together with the fact that no structural transformations occur until the melting point is reached.

The major difficulty associated with the use of cermets is, as is well known, their low resistance to impact. In this respect they compare unfavourably even with X-40, which is one of the most brittle of the high-temperature alloys. It is, however, obvious from the work reported that the range of properties which can be obtained in such materials renders them well worth further investigation in connexion with potential applications in high-temperature engineering.

Addition of Rare-Earth Metals and Compounds to Stainless Steels

C. B. POST and H. O. BEAVER: 'Use of Rare-Earth Metals and Compounds in Stainless Steel Melting.' *Yearbook, Amer. Iron and Steel Inst.*, 1953, pp. 183-8, 191, 194-6, 198-202, 204-7, 212-14.

See abstract of paper (as reported in *Blast Furnace and Steel Plant*) in *Nickel Bulletin*, 1953, vol. 26, Nos. 8-9, p. 151.

Shell Moulding of Stainless Steel

H. J. COOPER: '10,000 Stainless Steel Valve Bodies per year in Shell Molds.' *Precision Metal Molding*, 1953, vol. 11, Oct., pp. 44-5.

This short article gives a step-by-step description, with illustrations, of the technique of production of ½-in. valve bodies, which are being made in large quantity by the Cooper Alloy Foundry Company in stainless steel, using the shell-moulding process.

Use of Alloy Powders for Production of Iron Alloys and Steels

B. A. GRUBER: 'Alloy Powders by the Hydride Process.' *Proc. 9th Annual Meeting, Metal Powder Assocn.*, 1953, pp. 95-9; disc. pp. 99-101.

The work reported relates to 80-20, 50-50 and 20-80 chromium-nickel alloy powders prepared by the hydride process, and the properties of iron alloys and iron + graphite alloys in which such powders were incorporated. Cf. paper reported from *Precision Metal Molding*, 1953, vol. 11, Mar., pp. 42-5, 73-6; *Nickel Bulletin*, 1953, vol. 26, Nos. 8-9 and 10, pp. 157-9 and 178.

The author of the present paper records that although only chromium-nickel alloys are referred to in his paper, experiments have also been made with other metals, for example, titanium, zirconium, cobalt, tungsten, molybdenum and vanadium.

Hardenable Chromium-Nickel-Copper-Iron Alloy

'Hardenable Corrosion-Resistant Casting Alloy.' *Materials and Methods*, 1954, vol. 39, Jan., pp. 148-50.

This note describes a ferrous casting alloy essentially similar in composition to Armco 17-4 P.H., which has hitherto been available in wrought form only. The alloy, designated D.C. 50, contains carbon 0·05, chromium 16·5, nickel 4, copper 4, per cent. It is claimed to show corrosion-resistance superior to that of 12–14 per cent. chromium-iron alloys, and to be suitable for use in abrasive conditions. In the solution-treated condition the tensile strength is of the order of 135,000–165,000 p.s.i. (60·5–73·5 tons per sq. in.) and in the hardened state values of 180,000–210,000 p.s.i. (80·5–94 tons per sq. in.) may be obtained.

Influence of Cold-Working on the Magnetic Properties of Austenitic Chromium-Nickel Steels

S. STORCHHEIM: 'How Cold Reduction Affects Several Properties of 18-8 Stainless Steel Wire.' *Wire and Wire Products*, 1953, vol. 28, Dec., pp. 1310-11, 1314.

The information given is identical with that published in *Iron Age*, 1953, vol. 171, Feb. 12, pp. 140-2: see *Nickel Bulletin*, 1953, vol. 26, No. 4, p. 65.

Corrosion-Resisting Characteristics of Complex Chromium-Nickel Steels

W. E. PRATT: 'Worthite.' *Chemical Engineering*, 1953, vol. 60, Nov., pp. 264-78 (even numbers only).

This is one of the series of articles outlining, by means of charts, the resistance of specific materials to a

variety of corrosive reagents. The material considered is a complex corrosion-resisting steel of the following average composition: carbon 0·07 max., nickel 24, chromium 20, molybdenum 3, silicon 3·5, per cent., iron balance. Notes on mechanical and physical properties of the material, and on typical uses, are included.

W. A. LUCE: 'Durimet 20: Carpenter 20.' *ibid.*, Dec., pp. 276-88 (even numbers only).

This further article in the series evaluates, in like manner, the corrosion-resistance and the mechanical and physical properties of a cast and a wrought alloy, each having the following nominal composition: carbon 0·07 max., nickel 29, chromium 20, molybdenum 2 min., copper 3 min., silicon 1, per cent., iron balance. Durimet 20 is the trade name of the cast alloy as produced by the Duriron Company, Inc.: it is made by various other suppliers of cast alloys under other designations. Carpenter 20 is the trade name used by Duriron Company for the corresponding wrought alloy. The characteristics described in this article may be taken as representative of complex wrought stainless steels of these types.

Stainless-Steel and Nickel Equipment in Margarine Manufacture

'The Continuous Production of Margarine.' *Times Rev. Industry*, 1954, Jan., p. 15.

For many years the manufacture of margarine has been a lengthy process, involving large plant, much supervision, and considerable delays while the partly finished margarine is matured. This non-continuous system is now being replaced by continuous systems, by which a large output of margarine can be rapidly obtained from relatively small and compact equipment. Four plants of the new type are described in this article: the Votator, the Kombinator, the Rotocooler and the Rotosan.

Stainless steel is an outstanding feature of the various production units, and it is noted that in the Votator model the cooling and plasticizing cylinders are of nickel.

Clad Steel in Petroleum Equipment

A. HOERSCH: 'Clad Steel in Petroleum Equipment.' *Petroleum Processing*, 1953, vol. 8, May, pp. 700-3.

The author points out that, whilst clad steels are very valuable materials of construction for the chemical engineer, they must not be regarded as cure-alls, and that in each case the arguments in favour of clad steels vis-à-vis other materials should be carefully weighed in relation to the economic factors involved. As a practical contribution to the subject, he describes the choice made and the experience gained in six cases in which refinery engineers had to take a decision as to materials suitable in conditions which were border-line rather than clear cut.

The equipment discussed comprised:—

(1) A caustic regenerator used to strip mercaptans from a 10 per cent. solution of sodium hydroxide.
(2) A cracking vessel handling hot naphthenic-base crudes of about 1 per cent. sulphur content, operated at about 800°F. (425°C.).
(3) An acid-sludge-processing tank.
(4) A vacuum column vapour inlet handling naphthene-bearing stock under high-velocity conditions, where erosion rather than corrosion was the main problem.
(5) Spent-acid storage tanks and horizontal settlers in contact with dilute sulphuric acid of 65-70 per cent. effective acidity.
(6) A crude fractionator overhead condenser and accumulator handling a product containing appreciable quantities of hydrogen sulphide, hydrochloric acid and organic acids.

In each case details are given of the materials which met service requirements.

The remainder of the article contains tabular data on the types of clad steels used for vessels normally employed in various parts of oil refineries, their properties, and recommended technique for welding and flame-cutting them.

Monel Equipment in Fluorine-Disposal Plant

S. H. SMILEY and C. R. SCHMITT: 'Continuous Disposal of Fluorine: Reaction with Superheated Steam.' *Industrial and Engineering Chemistry*, 1954, vol. 46, Feb., pp. 244-7.

Extensive studies on the chemistry of fluorine, carried out during the past decade, have moved this element from the laboratory to the industrial sphere. The high reactivity of fluorine, its corrosive character, and its high toxicity have, however, involved many problems in storage, handling, and disposal.

Various methods have been proposed for disposal:—atmospheric dilution, reaction with water or steam, reaction with caustic soda solutions, combustion with hydrocarbon fuels, reaction with carbon or sulphur, absorption by lime or limestone, absorption by inorganic fluorides of low valence, and reaction with hydrogen. Operating difficulties, cost, and other features inherent in several of these methods render them unsuitable for general use, and some major difficulties are associated also with the atmospheric-dilution method, which is the most generally used procedure.

From the point of view of low cost, disposal of fluorine with water or steam is attractive, but until recently the reactions involved were considered to be uncontrollable, and therefore unsuitable as the basis for a reliable disposal method. The authors of the present article have, however, investigated, on a pilot-plant scale, a modified procedure in which pre-heated fluorine and superheated steam are employed. Full details of plant and procedure are given, with illustrations. The results promise useful development.

Particular attention is drawn to the suitability of Monel for construction of the steam-fluorine reactor parts. For the pilot plant described this alloy was used for the reactor nozzle and the spray-disposal tower, also for the reactor chamber, in which highly corrosive conditions due to contact with the gaseous hydrogen fluoride/steam mixture were involved. Monel

was selected on account of its known resistance to all concentrations of hydrofluoric acid over a wide range of temperature, and because, in the authors' experience, it provides excellent resistance under continuous exposure to gaseous hydrogen fluoride/water mixtures at temperatures of 1000°F. (540°C.). The same material was used for the fluorine pre-heater, in which temperatures of the order of 750°F. (400°C.) were involved. Inspection of the pre-heater at the conclusion of the pilot-plant tests showed no noticeable corrosion attack, and experience with Monel in the other components mentioned was also entirely satisfactory.

Oxalic-Acid Etching Test for Determination of Susceptibility to Intercrystalline Corrosion

'Electrolytic Etching of Stainless Steels.'

(1) M. A. STREICHER: 'Results of Co-operative Program for the Evaluation of the Oxalic Acid Etching Test.' *A. S. T. M. Bull.*, 1954, No. 195, Jan., pp. 63-7.

In the February 1953 issue of this journal M. A. STREICHER described an oxalic-acid etching technique which could be used as a supplement to (or, in some cases as a substitute for) the boiling nitric-acid test, for determination of susceptibility to intergranular corrosion of stainless steels: for details see *Nickel Bulletin*, 1953, vol. 26, No. 5, p. 88.

In view of the economy of time and cost which would be achieved by the use of such a test, the appropriate A.S.T.M. Committee undertook to explore its applicability, and to arrange for correlation of the results given by this test with those obtained by the standard nitric-acid procedure. Eighteen laboratories participated in the examination of the behaviour of certain standard steels under the two types of test: the results are summarized by STREICHER in the present report. The agreement reached by the co-operating laboratories was highly satisfactory: all classified the same steels in the 'pass' class, and all 'failed' the same specimens. Some irregularity was observed in the behaviour of a molybdenum-containing steel, indicating that minor modification of test procedure would be advisable in order to ensure satisfactory evaluation of this type of steel.

(2) F. H. BECK, N. D. GREENE and M. G. FONTANA: 'Electrolytic Etching in Oxalic Acid used to Screen Cast CF-8 and CF-8M Stainless Steels from the 240-hour Nitric-Acid Test', *ibid.*, pp. 68-71.

Cast stainless steels of the CF-8 and CF-8M types (see Table I) electrolytically etched in 10 per cent. oxalic acid at a current density of 1 amp. per sq. cm. for 1·5 minutes, showed one or more of the following structures:—

(1) Complete ditching of grain boundaries.
(2) Heavy etching of interconnecting ferrite stringers.
(3) Random pitting.
(4) Slight etching round ferrite pools.
(5) Little or no grain-boundary etching.

It is considered that only those cast stainless steels showing the structures described under (1) and (2) above should be subjected to the boiling nitric-acid test. All other microstructures are representative of steels having acceptable nitric-acid corrosion rates.

Table I

	C %	Si %	Mn %	Cr %	Ni %	Mo %
CF-8	0·064	0·70	0·47	18·15	9·75	
CF-8M	0·06	0·82	0·83	19·78	9·2	2·20

(3) G. W. JACKSON and W. A. LUCE: 'Screening Cast Stainless Steels by Electrolytic Etching in Oxalic Acid', *ibid.*, p. 71-4.

The tests reported in this paper were made on alloys CN-7M, CF-8 and CF-8M (see Table II), after preliminary investigations on wrought steels of standard A.I.S.I. 304 and 316 types. From the observations made, the authors conclude that the oxalic-acid screening test can be satisfactorily applied to both the wrought and the cast materials examined. They note that wrought steels may exhibit step structures (with no grain-boundary weakness), ditch structures (susceptibility to intergranular attack), or dual structures (combination of step and ditch structures), depending on the prior history of the material. Cast material, when correctly solution-quenched, can be

Table II

	C %	Si %	Mn %	Cr %	Ni %	Mo %	Cu %
CN-7M	0·07 max.	1·50 max.	1·50 max.	19-22	27·5-30·5	2-3	3·0 min.
CF-8	0·08 max.	2·00 max.	1·50 max.	18-21	8-11		
CF-8M	0·08 max.	1·50 max.	1·50 max.	18-21	9-12	2-3	

recognized only by a lack of ditching, since it will rarely exhibit a 'step' effect at the grain boundaries. Material requiring further evaluation on account of apparent susceptibility to intergranular corrosion will show almost continuous grain-boundary ditching, and this structure is readily recognizable.

All three reports are well illustrated by typical structures as revealed by the oxalic-acid test.

Properties and Uses of High-Temperature Brazing Materials

G. D. CREMER, F. J. FILIPPI and R. S. MUELLER: 'High-Temperature Brazing Applications.' *Soc. Automotive Engineers, Preprint* 148, Sept.–Oct., 1953; 14 pp. plus figures.

The paper deals objectively with brazing materials used for parts in which properties at elevated temperatures are of primary importance.

After an introductory discussion of brazing, and the specialized applications of bonding by brazing, the properties and uses of commercially available brazing materials are discussed in sections covering, respectively, nickel-base alloys containing boron and silicon, with or without chromium; silver-manganese alloys; manganese-nickel alloys; palladium-silver and palladium-nickel alloys; complex nickel-base alloys containing chromium, manganese, silicon, and boron, with additions of iron and molybdenum, and nickel-base alloys containing silicon, chromium, iron, boron and carbon. Information on copper is included for comparative purposes only, since it is seldom used for parts to be operated at high temperatures. Names of some of the proprietary alloys in the respective classes are given.

The paper contains a large number of photographs showing parts in which brazing materials of the various types have been used, and details of the brazed joints are given, with photomicrographic illustrations of the structure of some representative joints. The applications included cover brazing of several high-temperature alloys, e.g., Nimonic alloys, Inconel, nickel-chromium austenitic steels; they demonstrate the use of brazing for assembly of a wide range of components used in elevated-temperature service, and emphasize the extensive potential usefulness of this method of fabrication.

Silver Brazing of High-Chromium Steels: Nickel-containing Brazing Alloys

J. J. HALBIG, L. H. GRENELL and G. H. SISTARE: 'New Alloys Stop Corrosion in Silver-Brazed Type 430 Joints.' *Iron Age*, 1953, vol. 172, Dec. 10, pp. 159-63.

A more detailed report of this work is published in *Welding Jnl.*, 1954, vol. 33, Feb., pp. 137-43, in the form of a paper presented to the American Welding Society, Oct., 1953.

Type 430 chromium steel, which gives good resistance to corrosion in many environments, is easily fabricated, welded, and soldered, but when it is joined by certain silver-brazing alloys and exposed to tap water or to a humid atmosphere a small line of red rust forms at the edge of the brazing alloy. Resulting loss of strength in the joint speedily leads to failure. This condition, and the development of remedial measures, are the subject of the present paper, which covers investigation of preparation of the stainless steel before brazing, loss of strength on exposure (to tap water, humid atmosphere, and sodium-chloride solution), fluxes, brazing techniques, treatment after brazing, and the composition of brazing alloys.

The data obtained indicated that for prevention of deterioration it is necessary that the brazing alloy used shall be capable of depositing a nickel-rich layer over the area of the steel which is covered by the brazing alloy.

On the basis of the observations made on joints prepared with a wide range of brazing alloys, the following compositions were developed as suitable for this application: (1) silver 65, copper 28·5, tin 6, nickel 2·5, per cent., and (2) silver 60, copper 28, tin 10, nickel 2, per cent. Joints made with such alloys gave satisfactory behaviour under the experimental conditions of test. Nickel plating of the steel prior to brazing also prevents corrosion.

The paper contains detailed discussion of the nature of the deterioration occurring in the silver-brazed joints and the qualities required in an alloy in order to make it effective in producing the required nickel-rich layer over the critical area.

Weldability of Steels: Welding Research Council Handbook

See abstract on p. 46.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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